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## **Photonic Patterns: Fashion Cutting With Illuminating Polymeric Optical Fibre (POF) Textiles**

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### **Abstract**

Creative pattern cutting with conventional textiles can often achieve a diverse variety of effects ranging from the sculptural to minimalist simplicity. Conventional textiles have few limitations and can be manipulated to adhere to the creative demands of the designer. Current research of Polymeric Optical Fiber (POF) textiles have resulted in the creation of an innovative textile which is pliable and possess high tactile quality. However, the fundamental nature of the POFs is brittle thus susceptible to breaking when abruptly bent. In addition, the textile is dependent of the continuous structure of the POF to transmit light. Using the researcher's practice as the main case study, this paper will explore the challenges of designing and pattern cutting POF textiles to create dynamic fashions which are adaptive and serve as a sustainable and alternative platform for communication.

### **Introduction**

Illuminative POF textiles which are adaptive to the consumers' needs have great applicability in fashion design. It pushes the boundaries of a conventional passive garment into an interactive platform which can be used for effective communication between the wearer and the viewer. Utilizing different colored lights has the emotive power of affecting people from different geographical locations and (Xin et al., 2004). POF textiles allow users to easily customize their clothing with the emitting of different colors, rhythms via portable remote controls.

POF textiles can be created using different weaving methods. The mixture of conventional textile based yarns like cotton, polyester and wool can be woven with POFs to create the illuminating textiles with positive hand feel. POF textiles utilize the strands of POFs to transmit light throughout the fabric. The placement of the electronic components, power source and the actual cutting of the fabric will affect the illumination effect of the POF textiles on the garments.

Existing literature on POF textiles had mainly focused on the technological aspects and while the author of this paper had presented research based on POF textiles' design process, there is a gap in the exploration of the pragmatic pattern cutting aspects of POF textiles for fashion. This paper will discuss various existing illuminating textiles, the technological background of POF textiles and citing one of the researcher's prototypes as the main case study, the paper will further explore the challenges of pattern cutting with POF textiles.

### **Illuminating Textiles**

Fashion garments which illuminate has been on the market for many years. Illuminating fashion which emit light and color displays, worn by performers can create a dynamic visual spectacle for viewers (Cute Circuit, 2006). Performers can gain high visibility in large performance arenas

and create dramatic effects in dark conditions. Different technologies can be applied to create illuminating effects on textiles such as the placement of Light Emitting Diodes (LEDs) onto the fabric, electroluminescent materials and via the use of POF textiles.

Cute Circuit had created many eye catching illuminating costumes for high profile, American singer, Katy Perry, an example is the glowing gown which she wore to the MET Costume Institute Gala in 2010 as shown in Fig.1 (Cute Circuit, 2010). The chiffon dress had thousands of micro LED lights applied on the layers of fabric creating a shimmering rainbow of colors. The light is directly emitted from the LEDs, while the fabric just acts as the base material creating the form and structure of the dress.

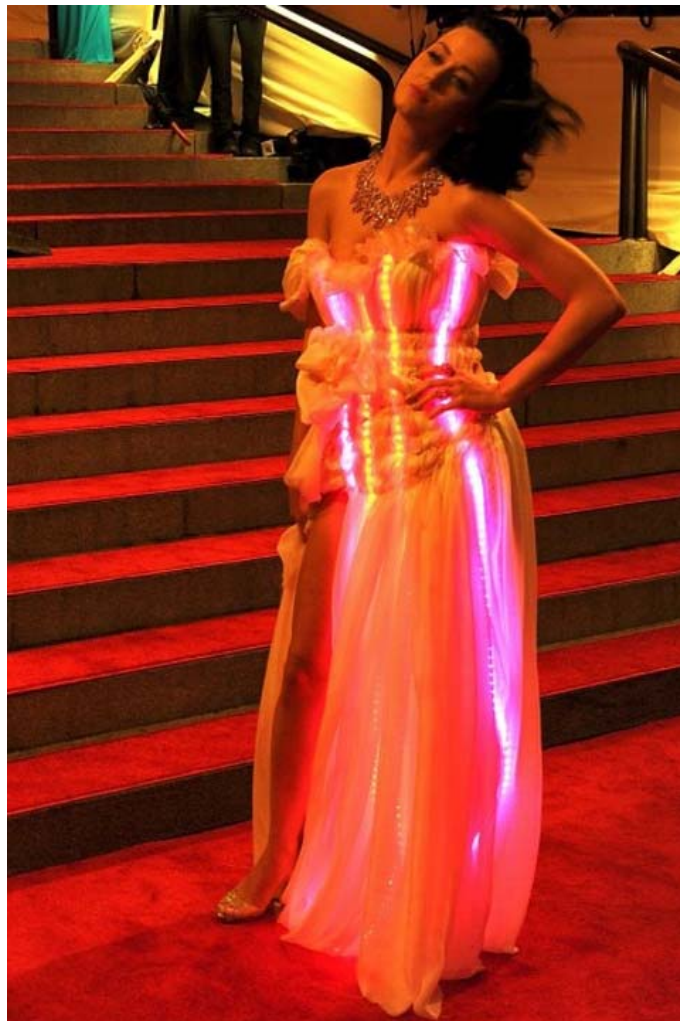


Fig.1: Katy Perry stage costume by Cute Circuit

In 2011, PEGA Design & Engineering cooperated with Taiwan Textile Research Institute to create a LED yarn. (PEGA, 2015) The LED yarn was applied onto a cycling jacket, entitled Light Fairy, to improve the night visibility of cyclists. Light is only emitted from the LED yarn thus limiting the

area of illumination and only one color can be emitted as shown in Fig.2. The yarn possesses conductive fibers with embedded LEDs. Dotted illuminating lines are shown on the surface where the LED yarns are inserted in the fabric. The LED yarn can only emit light from the singular yarn thus limiting the area of illumination. It primarily serves as a visibility aid in dark conditions and does not possess any interactive functions.



Fig.2: LED yarn developed by PEGA Design and Engineering.

The History Tablecloth developed by Gaver et. al (2006) utilizes electroluminescent material screen printed on a flexible substrate. It is reliant on the electric current emitted by components beneath the tablecloth to illuminate. The display is large and possesses low resolution; however, it takes the form of the screen printed lace like pattern when illuminated. The table cloth reacts to the flow of the everyday objects thus highlighting the hidden narratives in everyday activities.



Fig.3: 'History Table Cloth' printed with electroluminescent inks developed by Equator.

Urban Glow is a Cheongsam designed with photonic textiles developed by the author of this paper. (Tan, 2013) The traditional Chinese dress was designed in collaboration with the Hong Kong Museum of History for their Legacies & Innovations exhibition and fashion show. The photonic textile was woven in plain weave; the POFs transmit light from the LED light source with light illuminating evenly from the entire fabric. In contrast to the above mentioned examples, light is emitted from the entire POF textile and not limited to the areas around the LEDs or the LED yarns. The POF textile possesses integrated sensors within the components and can emit different colors in various rhythms. The dress also has integrated Bluetooth technology which allows the POF textile to be remotely controlled by a typical Android phone. POF textiles are woven with any textile based yarns such as cotton, to create textiles which possess positive tactility. They are highly adaptable and can be customized according to the preferences of the user. The technological components are small allowing ease of integration.



Fig.4: 'Urban Glow', dress made from POF textiles developed by Tan.

Each of the examples cited above had utilized different technologies and application methods to create illuminating textiles. POF textiles offer the following advantages,

- 1) The POF textile is a woven fabric, offering users the touch comfort of a fabric without the cumbersome feel of components within the structure of the fabric.
- 2) The light illumination of POF textiles can be evenly distributed throughout the fabric or treated to emit specific patterns, there is no limitation as to where the light will be emitted on the fabric.
- 3) The components for the POF textiles can be applied away from the textile thus not affecting the integration of technology can be seamless and not affect the overall design or structure of the garment.
- 4) POF textiles are highly portable with very small components which can be easily integrated into the structure of the garments.

### **POF Textile Technology**

#### **Lateral transmission of light**

The utilization of glass optical fibers to transmit light had been demonstrated more than 150 years ago ((Brochier and Lysenko, 2008). The cost of production for POFs is lower than conventional glass fibers yet they retain the same advantages. Contemporary POFs have good flexibility thus can be woven with conventional yarns like cotton, polyester or wool to create smart textiles with good tactile qualities. The familiarity of touch for these innovative textiles makes them viable to be integrated into everyday products which can improve quality of life for consumers.

The fundamental composition of a POF comprises of the core and the outer cladding. Light is transmitted through the core from one end to the other. In the context of a POF textile, light will need to emit from the lateral side of the fiber. Lateral light transmission can be achieved by damaging the cladding of the fiber to allow the light to seep through the cracks on the fiber. The cladding can be damaged via chemicals or physical methods such as notching (Koncar, 2005), abrasion (Im et al., 2007), or sandblasting (Endruweit et al., 2008).

However, such methods often deliver unstable results as they damage the fibers thus weakening their core structures. Such methods cannot be controlled with precision and may result in an uneven distribution of light throughout the textile. This will be problematic as the uneven distribution of light may affect the overall visual aesthetic of the fashion design.

The researcher had adopted laser engraving to create precise damage on the POF textile to enable lateral light emission. The laser engraver (Fig.5) utilizes a computer controlled carbon dioxide laser which emits at a specific wavelength at the far infrared region of the electromagnetic spectrum. This method is very specific and can engrave detailed motifs onto the POF textiles allowing different patterned light to be illuminated. The power of the laser is determined by the resolution (in dpi) and pixel time (in  $\mu\text{s}$ ). The alteration of different combinations of resolution and pixel time will create different illumination effects.

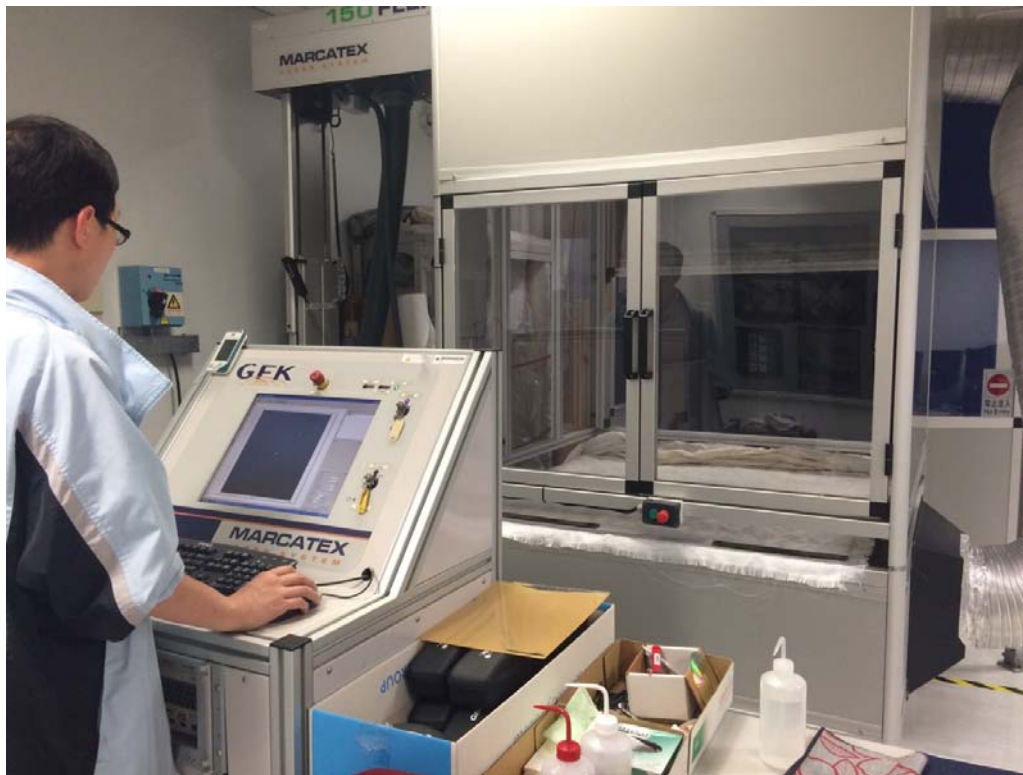


Fig.5: Laser engraver

### Light and power sources

In order to illuminate, the POFs are connected to a light source, power source and a motherboard. LEDs serve as the light source, as they are lightweight, requires very little power to run and the components transmit very little heat thus making them comfortable light sources for fashion garments. Portable batteries such as slim mobile phone batteries are light and can be easily integrated to the inner structure of the garment without affecting the silhouette of the garment. The motherboard can be designed to incorporate different sensors and programs to create different illumination and interactive effects.

### Woven vs. Knitted structures for POF textiles.

Although POFs are highly flexible, abrupt folding and bending will result in the breakage of the core thus causing light to leak at the point of breakage. Therefore, it is more viable to create POF textiles via weaving than knitting. A typical knit structure will require the fibers to bend extremely to create the loops necessary to create the knit structure as shown in Fig.6. Weaving allows the fiber to be arranged in exact positions (Abouraddy et al., 2007), thus creating a stable surface which is unlikely to create sudden structural bends. Different weaving methods and structures can create a variety of effects and forms on the textile.

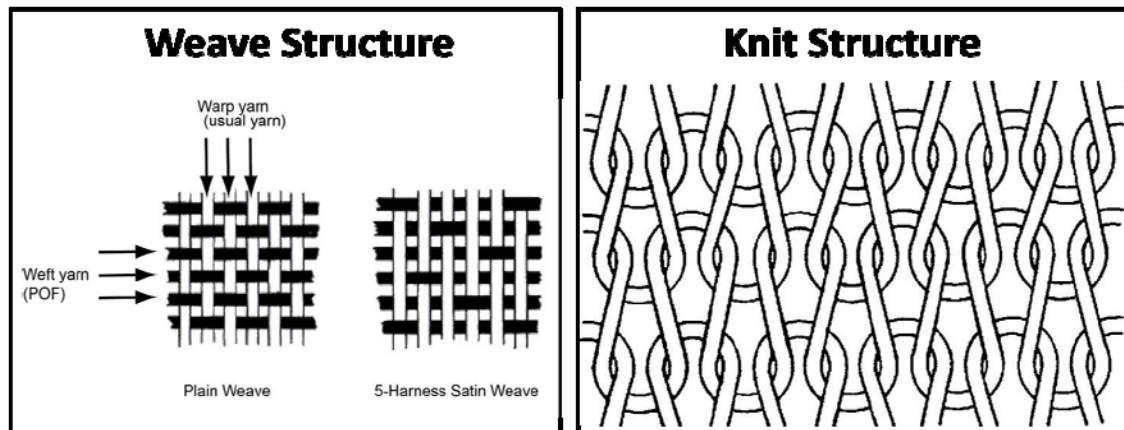


Fig.6: Close up view of weave and knit textile structures.

### POF Fashion Prototype: Lucid Illumination

In order to explore the practicalities of designing and pattern cutting for a fashion garment using POF textiles, this paper will utilize the author's design prototype as the main case study.

### Design Inspiration

*Lucid Illumination* is a childrenswear fashion outfit designed for a girl of 5-6 years old. It was designed in collaboration with the Hong Kong Heritage Museum for their "Hidden Meanings in Chinese Children's Clothing" exhibition in December 2015. The design was influenced by historical costumes of the Qing Dynasty in China. In conjunction with the theme of the

exhibition, to explore narratives in clothing, it was critical for the POF textile's design to reflect the era in which the garment design was inspired from (Fig.7).

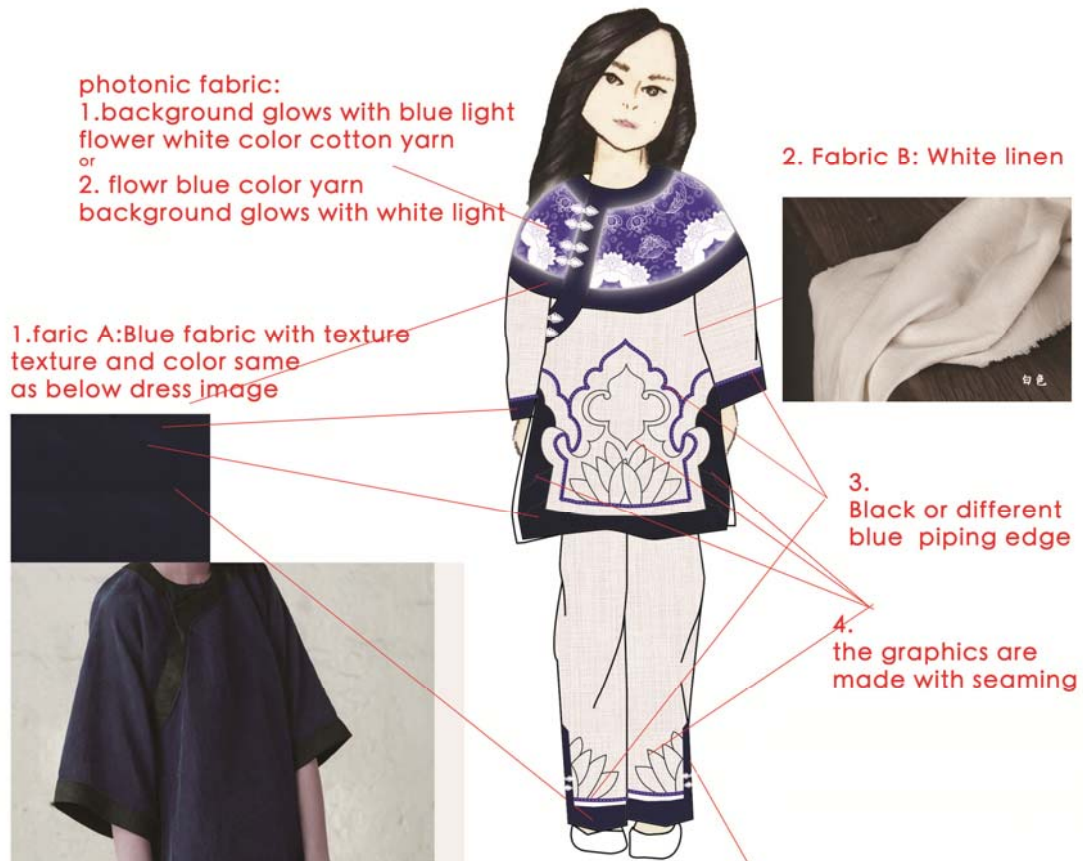


Fig.7: Development sketch of Lucid Illumination.

The POF textile design was inspired by the traditional Chinese blue and white porcelain with important cultural representative flowers the peony against a background of intertwining leaves (Fig.8). The intertwining leaves represents everlasting (Mu, Gu & Chen, 2008) while the peony flower represents prosperity (Lam, 2009 & Cheng, 2005). The floral design can be applied on the POF textile in various methods such as embroidery, printing or laser engraving (Tan, 2014b & 2013a). As existing research often explores POF textiles which are flat with applied surface decorations, this study will explore the innovative introduction of texture and pattern via Jacquard weaving. The floral motif was designed to be woven via Jacquard to create an intricate woven pattern. The Jacquard weave will create a textured surface creating a more dimensional visual aesthetic and handle. The POF textile was woven on the Dornier Weaving Loom PTV 8/J with the STAUBLI Jacquard Head JC6 (Fig. 9).



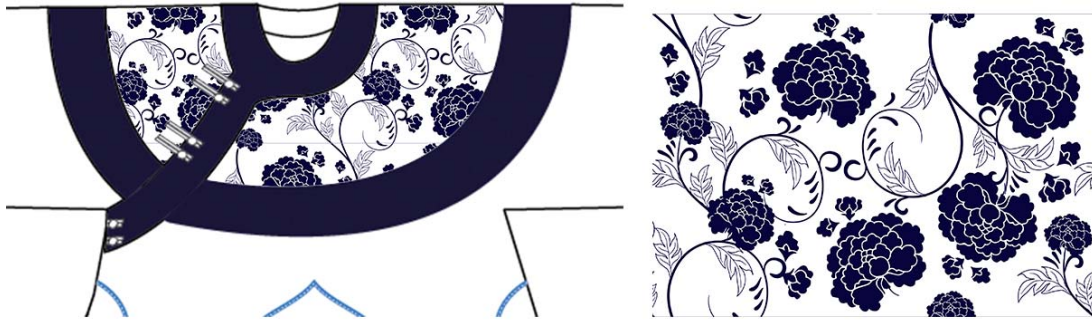


Fig.8: POF textile design with peony and intertwining leaves.



Fig. 9: Dornier Weaving Loom PTV 8/J with the STAUBLI Jacquard Head JC6.

Little had been explored in terms of creating obvious textures with POF textiles. Creating textured POF textiles is particularly challenging as it will introduce bends in the POFs which may expose them to a higher possibility of breakage due to the fiber's rigid nature. The breakage of

the POFs will affect the even distribution of light on the surface of the textile. The broken fibers will create 'spots' where light will leak at the point of breakage. Insufficient bending of the fibers will result in a typical flat POF textiles, therefore the textile development of the textile was put through multiple experiments and sampling to create a textile with even light distribution.



Fig.10: Jacquard weave POF textile for Lucid Illumination

#### Integration of Power Source and Electronics.

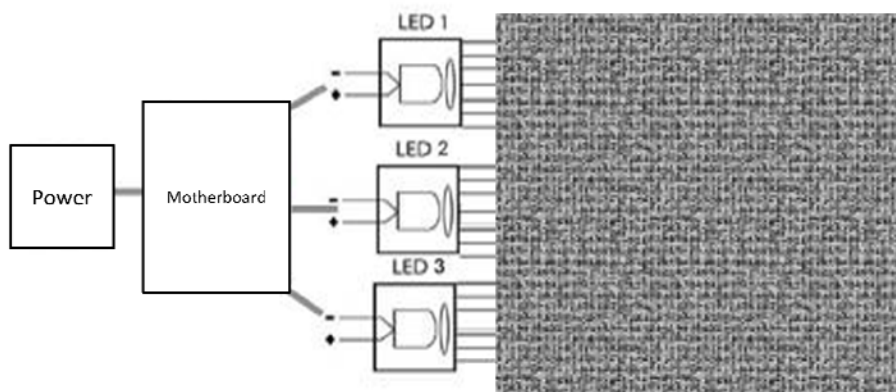


Fig.11: Schematic diagram of POF textile's connections to light source, motherboard and power source.

Fig. 11 shows a diagram of how the POF textile is connected to the electronic components. LEDs are used as the light source for POF textiles. Groups of POFs are bundled together can

connected to the LEDs. Earlier research by the author had utilized the ultraviolet bonding technique (Bai & Tan, 2011) utilizing a specialized glue. However with further research and experiments, the research team had developed a coupler to efficiently connect the POFs to the LED light source without the use of messy glue (Tan, 2013a).

The textile and the LEDs are also connected to the motherboard which is integrated with programs or sensors which are pertinent to the design of this particular textile. The inclusion of sensors and programs allows a conventionally passive textile to become an interactive platform which can be customized to the needs of the individual users.

A variety of power sources can be used for the POF textiles, ranging from conventional batteries in a variety of sizes to plugging the textile to an AC/DC power supply. It is vital to choose a small and portable form of power supply for the fashion designs to enable the wearer to move freely and integrate the technology in an unobtrusive manner. Although the electronic components are small and light, they were designed to be applied in fashion design, the research team had to customize the components and plan the placement of the components at strategic positions to not affect the aesthetic design of the garment, the comfort of the wearer and enable easy access to the components when not using the remote control.

To encourage the wearer and the viewer to easily interact with the POF textile, the researchers have integrated a remote control function via Bluetooth technology. The textile can be remotely controlled via a specific app downloaded onto any typical Android mobile phones.

### **Considerations during the pattern cutting process**

Pattern cutting is a vital process within fashion design. The process translates conceptual design ideas into three dimensional structures via two dimensional patterns. Conventionally, pattern cutting can be a relatively isolated activity, in which the pattern maker interprets a specific production drawing by the designer to create the pattern. The utilization of POF textiles in fashion design involves interdisciplinary areas like textile technology, textile design and fashion design. Working with POF textiles, all three areas are considered to create an aesthetic design which is cohesive and functional.

The main factors which will affect the pattern making process when using POF textiles are,

- 1) The placement of the POF textile
- 2) The placement of the power source and electronic components.

POFs will break when abruptly bent, it is ideal not to place the POF textiles around the elbows, waist and knees. These are areas where the body will bend to accommodate movements. However, the fabric can be rolled along the lateral length for easy storage without breaking the

fibers. In this design, the POF textile had been placed around the shoulders where the wearer is unlikely to bend the textile and thus creating damage.

It is also ideal to consider placing the POF textile as a whole piece on each garment instead of cutting and sewing multiple POF textiles. The rationale being that each POF textile will require separate power and light sources, thus requiring multiple electronic parts which may be cumbersome and affect the aesthetic design of the garment.

The POF textile is reliant on the fibers to transmit light, the connection between the fibers and the components have to remain intact in order to ensure an even distribution of light. As the light source can be located away from the actual fabric panel, the components can be placed in at different locations where it is more convenient for the wearer to gain access to. The allocation of the components has to be considered to allow specific compartments to be incorporated into the pattern of the garment to hold the small components in a fixed and unobtrusive position. A specific internal compartment can hold the components or they can be sandwiched between the facing and the internal lining.

In conventional pattern cutting processes, the fabrics can be freely cut on the grain, bias or in any direction to achieve the desired effect. Cutting of panels and sewing them in different patterns can help achieve various fits and design aesthetics. However, the POF textiles are woven with the textile based fibers on the warp and the POFs on the weft.



Fig 12: POFs woven via the weft and bundled together to connect to the light source.

Theoretically, POFs can be woven via both the warp and weft directions. For the convenience of changing the yarns, POFs are usually integrated in the warp direction for hand weaving loom, while weaving POFs via the weft direction is adopted for machine weaving loom. Moreover, studies on the luminosity of woven textiles in warp and weft direction demonstrated that POFs woven in weft direction showed better illumination results (Koncar, 2005, Harlin et al., 2003, Masuda et al., 2006). For this research, machine weaving loom was chosen because of its highly efficient performance. POFs are only woven into the weft direction with other conventional yarns. Otherwise, the tactile quality will be greatly reduced if POFs are woven via both weft and warp directions.

During the pattern cutting stage, it is vital to take special attention not to fold the fabric along the grain. As the POFs are woven via the weft, folding the fabric along the grain will result in breakages of the fibers. Instead, the textiles can be rolled along the weft without bending the POFs. The textile cannot be cut along the grain as it will interrupt the delivery of light from the light source across the fabric. Each pattern piece had to be individually cut flat on the POF textile thus incurring a more labor intensive process.

The textile based fibers which are woven via the warp will be removed by hand to leave sufficient space for the seam allowance and exposing lengths of the POFs, which will be

connected to the electronic components and the power source (Fig. 12). Another reason for removing the unexposed textile based fibers is to reduce bulk along the seam allowances, therefore not affecting the silhouette of the garment.

As the POFs are woven in a specific direction, the connecting components can be placed away from the textile but abrupt bends in the POFs have to be avoided. The POF textile panels have to be calculated and planned in advance as they cannot be cut and sewn randomly. It is advantageous that the components can be placed away from the POF textile. This will allow the components to be placed in various positions as to not create cumbersome bulk beneath the garment. It will also allow the components to be placed at areas which will allow the wearer easy manual access to the controls of the garment. This will allow the wearer two control options in the form of the attached manual control and the remote control. The viewers will also be able to interact with the garment via the remote controls.

The ability to place the components away from the POF textile can be both advantageous and disadvantageous. The flexible placement enables the designer to explore a wide variety of structural shapes and style lines thus not restricting creativity. The main disadvantage is that the distance between the light source and the fabric will affect the brightness of the illumination. In this context, the pros outweigh the cons as the illumination can be tweaked by adjusting the light source.

### **Conclusion**

Pattern cutting is a vital garment making process which creates form and structure. Different factors are considered when handling different types of fabrics to achieve various drapes and shapes. Within the context of this research, the POF textiles possess specialist fibers which are woven in a specific direction. While most conventional textiles can be cut and sewn in any order to create a functional garment, the POF textile in this research had to be cut and placed strategically in order to facilitate the illumination of the fabric.

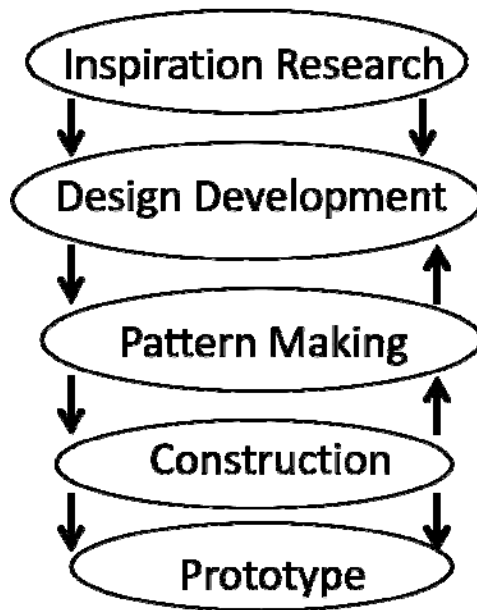


Fig.13: Diagram of a conventional garment development process.

The development of fashion designs utilizing POF textiles require an interdisciplinary approach whereby design and technological considerations contribute to the creation of interactive garments which are functional and possess aesthetic appeal. It is noted that the simplistic application of the POF textiles onto a fashion design which was designed separately and without the consideration of the textile's technology, physical characteristics and design will result in a cumbersome integration of technology creating poor aesthetic appeal and functional ease. A typical design process may comprise of a systematic progression of the different activities with flexibility to go backwards and forwards in order to refine the design (Fig.13).

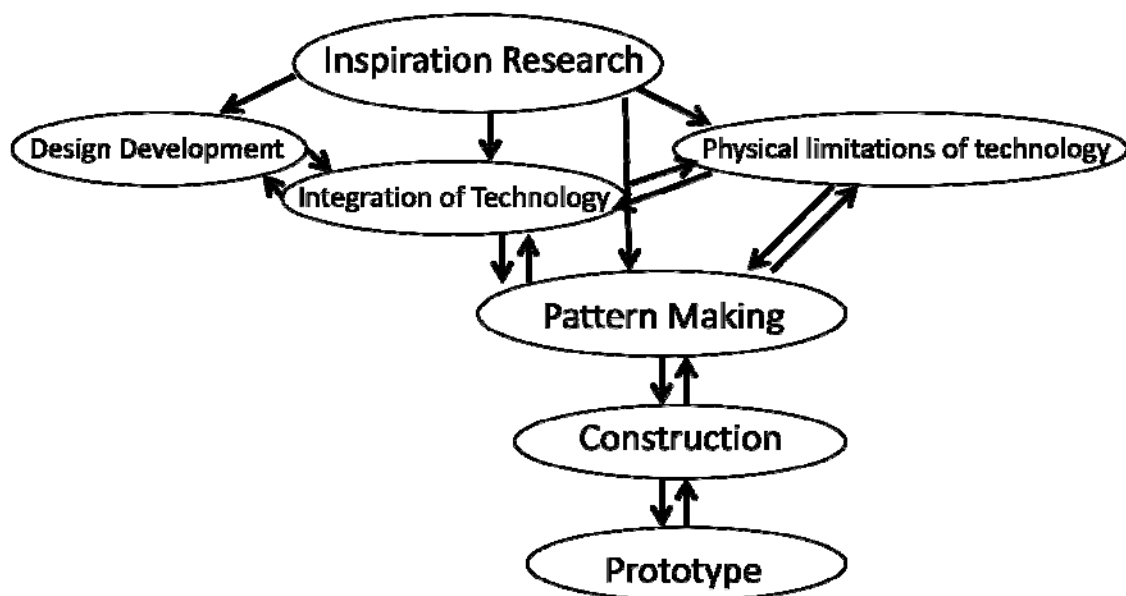


Fig. 14: Diagram of the fashion design process involving POF textiles.

The design process of a POF fashion design requires a more complex process as there are many factors which are required to be synchronized. It is vital to consider the fashion design, the POF textile design, the POF technology and components in tandem. Each factor does not work in isolation as each contributes to the overall design of the garment. The design, development, pattern cutting and construction of the garment requires a flexible design process whereby the design can be constantly refined via experiments to create fashion designs which are interactive and user friendly (Fig.14). Pattern making is the most critical activity in the design process which enables the POF textiles to be transformed into wearable garments. The absence of sophisticated pattern cutting knowledge will result in the simplistic application of technology creating garments which are not comfortable and user friendly. Gimmicky technological applications will result in garments which are easily replaced.

The design objective of utilizing interactive POF textiles in fashion design is to enable users to customize their clothing and create alternative platforms in which users and viewers can communicate. Such clothing will also allow many viewers and users to collectively participate in visual spectacles which will encourage contact and creativity.

Interactive clothing which utilizes POF textiles has the potential to be developed into life enhancing products in many areas such as visual performance, sustainability design and healthcare. The advancement of technology had witnessed the miniaturization of electronic components enabling the technology to be comfortably applied onto garments with close contact to the body. With further research, POF textiles will contribute to the pushing of boundaries of wearable technology.

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